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Factsheet

NITROGEN FERTILIZER MATERIALS FOR FIELD CROPS

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Nitrogen and Plants

Nitrogen is one of sixteen elements that are essential for the growth of plants. It is a component of proteins and is therefore involved in regulating most processes that occur in plants. A deficiency of nitrogen causes poor growth, stunted plants and low yields. Because nitrogen is a component of chlorophyll, a yellow color, beginning with the lower leaves, is a common symptom of nitrogen deficiency.

Nitrogen tends to promote vegetative growth relatively more than reproductive growth. Plants given excess nitrogen tend to be tall with weak stems. Thus, an oversupply of nitrogen can cause lodging.

Nitrogen in the Soil

Most of the nitrogen taken up by plants is in the form of the nitrate ion (NO_3^-), although a small amount also is taken up in the form of the ammonium ion (NH_4^+). Most of the nitrogen in soil is contained in the organic matter, and is not available to plants until the organic matter decomposes. Of the nitrogen contained in the organic matter, only 1% to 3% is released annually. Most of the available nitrogen in soil is in the nitrate form, since ammonium nitrogen is converted relatively quickly to nitrate by soil bacteria. (For further information, see OMAF Factsheet *An Introduction to Soil Fertility* Agdex 530.) The nitrogen in the fertilizer materials discussed in this Factsheet is present in one or both of these forms, or is quickly converted to either the ammonium or nitrate form in the soil.

Nitrogen Materials

Several fertilizer materials that supply nitrogen are available to Ontario farmers. In their manufacture, natural gas is first reacted with nitrogen gas from the atmosphere to produce ammonia, which is then used as the raw material in making other nitrogen materials. All are effective in supplying nitrogen for crops when used properly, but they differ in cost, safety, convenience, equipment requirements and compatability with other products.

Anhydrous Ammonia

Anhydrous ammonia is the most concentrated source of nitrogen available (82% N). Because it requires the least amount of manufacturing, it is also the least costly source.

Although ammonia is very volatile and exists as a gas at temperatures over -33°C, it is handled and applied as a liquid under high pressure (500 to 1050 kilopascals). Therefore, equipment (i.e. tanks, hoses, fittings, meters, etc.) capable of withstanding these pressures must be used.

Anhydrous ammonia is a very hazardous material and can cause injury or death in several following ways: (1) When liquid anhydrous ammonia vaporizes, it absorbs a large amount of heat from its surroundings, dropping their temperature to about -33°C. Liquid ammonia will freeze skin or other tissues almost immediately upon contact. (2) Ammonia is very alkaline and very caustic. (3) Because it attracts water, ammonia will draw moisture from tissues, causing a burning effect. Body tissues that have a high moisture content, such as the eyes, lungs, and linings of the nose and throat, are especially vulnerable. Even relatively low concentrations of ammonia in the air can cause irritation and damage to these tissues. (4) At high concentrations, ammonia causes death by suffocation.

Always wear protective clothing when handling anhydrous ammonia. This includes long sleeves, impervious rubber gloves and properly fitted, non-vented goggles. Water is the best first-aid treatment for ammonia burns. Flush exposed areas of skin or eyes with clean water for at least 15 minutes. Always have a large supply of clean water immediately available when handling anhydrous ammonia.

For corn, anhydrous ammonia can be applied either preplant or side-dressed. In southwestern Ontario, ammonia has shown a slight yield advantage over other nitrogen sources for corn, and less is required when it is applied side-dressed than when applied preplant. In the rest of Ontario, there has been no difference among sources or application methods. (See OMAF Factsheet, *Nitrogen Recommendations for Corn* Agdex No. 111/541.)

Table 1 Properties of Liquid Nitrogen Materials

Material	% N by weight	Salting Out Temperature (c)	Vapour Pressure @40 C (kPa)	Density @16 C (kg/L)	N Content (kg N/L)
A: High Pressure					
Anhydrous Ammonia	82	–	1455	0.62	0.51
B: Low Pressure					
Aqua Ammonia	20	- 75	14	0.91	0.19
41% N solutions					
(22,65,0)*	41	- 6	69	1.13	0.47
(19,58,11)**	41	- 14	69	1.16	0.48
C: Non-pressure					
28% N solution	28	- 18	0	1.28	0.36
32% N solution	32	0	0	1.32	0.43

**Contains 22% ammonia, 65% ammonium nitrate and no urea by weight*
***Contains 19% ammonia, 65% ammonium nitrate and 11% urea by weight*

Anhydrous ammonia must be placed under the soil deeply enough to prevent it from escaping into the air. With conventional equipment, a knife is used to open a slot, 15 to 20 cm deep, into which the ammonia is injected. The slot is then covered with soil. If anhydrous ammonia is knifed into soil that is too wet, hard or cloddy to seal properly, a large proportion of it can be lost. Equipment is also available to allow application of anhydrous ammonia using a disk or cultivator.

Ammonia is a clear, colorless gas. When it vaporizes, however, the low temperature causes water vapour in the air to condense to fog. Because a small amount of ammonia can cause the condensation of a relatively large amount of vapour, ammonia losses usually appear worse than they actually are. For example, it has been estimated that 2 ounces of ammonia can produce 13 gallons of mist.

Ammonia is toxic to plants. To prevent damage to germinating seeds or seedlings, preplant ammonia should be applied at least 10 cm deep, with the seed being planted no more than 4 cm deep. The applicator outlets should be no more than 50 cm apart to minimize the concentration of ammonia within the band. Otherwise, delay planting for several days after ammonia application.

Because anhydrous ammonia is very cold and very alkaline, some soil organisms are killed in the zone where the ammonia is applied. However, the effect on the soil is temporary. As the nitrogen spreads out from the treated band and becomes less concentrated, soil micro-organisms rapidly recolonize the zone to take advantage of the increased amount of available nitrogen.

Use of anhydrous ammonia has sometimes been cited as a factor in increasing soil hardness. At the rates used in crop production, anhydrous ammonia does not itself make the soil harder, nor do other nitrogen materials. However, because nitrogen fertilizers do not supply organic matter to the soil, as forage legumes and livestock manures do, the organic matter content of soil may decline if only commercial fertilizers are used. This, in turn, can lead to degradation of soil structure and increased hardness, unless the soil is managed properly.

In the soil, ammonia spreads through the pores spaces until it is completely dissolved in the soil moisture. At this stage, the nitrogen is present in the ammonium form and can be held on the cation exhange sites in the soil. (See OMAF Factsheet *Introduction to Soil Fertility*, Agdex 530.) Eventually, the ammonium nitrogen will be converted to nitrate which can be lost from the soil by leaching or denitrification. Products, known as nitrification inhibitors, that slow this conversion are available although they are not commonly used in Ontario. By keeping the nitrogen in the ammonium form longer, these products should reduce the loss of nitrogen from leaching or denitrification.

Low-pressure Solutions

Two types of low-pressure solutions are available in Ontario (Table 1). Aqua ammonia is made by dissolving ammonia in water and contains 20% nitrogen.

The 41% nitrogen solutions are made from ammonia and either ammonium nitrate or a combination of urea and ammonium nitrate. Because the ammonia is volatile and develops a low pressure, these solutions must be handled with equipment designed for low pressure. In most other respects, they are used and behave in the soil in much the same manner as anhydrous ammonia.

Non-pressure Solutions

Non-pressure nitrogen solutions are made by dissolving a mixture of urea and ammonium nitrate in water. These solutions are often referred to as UAN, the acronym for the ingredients. The two formulations of UAN used in Ontario contain 28% and 32% nitrogen, respectively (Table 1).

At low temperatures, the nitrogen salts in UAN can crystallize or "salt out". Because 28% UAN salts out at a lower temperature than 32% UAN, the former is used more commonly in Ontario. The 28% UAN can be stored over winter, but 32% UAN cannot. The 32% UAN is used only in warm weather, and cannot be combined with pesticides.

Since half of the nitrogen in UAN comes from each of urea and ammonium nitrate, the response of crops to UAN is similar to their response to an equivalent amount of nitrogen supplied by either material.

UAN can be applied preplant, pre-emergence or side-dressed. Most often, it is sprayed on, but it can also be knifed in using a modified ammonia applicator or similar equipment. Since UAN does not develop any pressure, it can be applied with conventional spraying equipment. Because UAN is denser than water, the flow rate of UAN is about 88% of that of water. The calibration of spraying equipment should be adjusted accordingly.

UAN is very corrosive, especially to brass. Equipment used to handle or apply UAN must be made of corrosion resistant materials. It is also a good idea to rinse equipment used when applying UAN thoroughly with clean water after use to prevent corrosion.

UAN is not volatile and does not have to be injected into the soil. However, because UAN does contain urea, there can be some loss of nitrogen when UAN is left on the soil surface or on crop residues. (See section below on "Ammonia Volatilization".)

If UAN is injected into the soil at planting and more than 55 kg of actual nitrogen per hectare is applied, the UAN should be applied at least 15 cm to the side of the row to minimize the risk of damage to the seed. The placement depth is not critical; as long as the UAN is placed in moist soil, the nitrogen will be available to the crop. Placing the UAN 7.5 cm or deeper in the soil should be sufficient to eliminate the risk of ammonia volatilization.

UAN is generally not used post-emergence because it can damage foliage. It is possible to use UAN safely on winter wheat when the crop is still small. To minimize damage the UAN should be dribbled on or applied as a spray coarse enough to run off the leaves.

If UAN is applied post-emergence in corn, it must be directed so that it does not contact the leaves. Otherwise, there will be considerable damage to the leaves and a yield loss can occur.

UAN (28%) is frequently mixed with herbicides to reduce the number of trips over the field. Certain herbicides or herbicide combinations are very difficult to mix with UAN. Herbicides that are not compatible with UAN can become gummy and plug the sprayer. It is advisable to do a compatability test when combining a herbicide or herbicide mixture with a source of UAN for the first time. The addition of a compatability agent to the mixture will help reduce the problems.

Solid Nitrogen Materials

The two solid nitrogen materials used most commonly in Ontario are urea and ammonium nitrate. A small amount of ammonium sulphate, a by-product of the coke industry, is also used. These sources are equally effective when used properly.

For spring-planted crops, the solid forms of nitrogen are commonly broadcast and worked in prior to planting. With some limitations, they can also be broadcast pre-emergence (See section below on Ammonia Volatilization). For winter cereals, the nitrogen should be top-dressed in the early spring (mid-March to mid-April). Forage grasses, pastures and spring cereals can also be top-dressed when the crop is small.

Since fertilizers that supply nitrogen or potassium attract water, they can damage germinating seeds or seedlings. This is called a salt effect. It can occur whether the fertilizer is applied in dry or liquid form. If too large a concentration of nitrogen or potassium is placed near the seed, water is drawn out of the seeds or roots causing them to die. The risk of damage is greatest on coarse-textured soils and in dry soils. (See *Fertilizer Toxicity* section in the *Soil Management* section of OMAF Publication 296, *Field Crop Recommendations*.) Urea is particularly toxic to seedlings because it has both this salt effect and the potential to produce free ammonia.

Fertilizers containing nitrogen materials can be used as carriers for certain herbicides. However, some herbicides registered for dry impregnation are compatible with only specific fertilizer materials. Be sure to check the herbicide label before mixing.

Ammonium Nitrate

Ammonium nitrate contains 34% nitrogen. Usage of ammonium nitrate is declining because of its higher cost and lower nitrogen content relative to urea. Since ammonium nitrate is highly combustible and highly explosive, it must not be stored where there is any risk of fire.

Urea

Urea is now the most commonly used solid nitrogen material. It is a more concentrated material (46% nitrogen) and is generally less expensive than ammonium nitrate. Urea is also easier to store in bulk because it draws less moisture from the air and there is no risk of fire or explosion.

Many people mistakenly believe that urea is a slow-release form of nitrogen, perhaps because of a confusion with sulphur-coated urea (SCU), a slow-release material used in some lawn and garden fertilizers. Urea cannot be called a slow-release form of nitrogen. Even in relatively cool soils, the conversion of urea to ammonium occurs within a few days after application. The conversion to nitrate begins almost immediately and will be complete within 3 or 4 weeks following application.

Ammonia Volatilization

As was mentioned above, when ammonia is dissolved in moisture, ammonium ions are formed. This reaction,

however, is reversible; ammonium nitrogen can revert back to ammonia. If this occurs at, or near, the soil surface, the ammonia will be lost to the air. Many factors determine the extent of the nitrogen loss. These include the nitrogen material used, the rate and method of application, the pH and buffer capacity of the soil, the weather, and the amount of crop residues. Under some conditions, up to half of the applied nitrogen can be lost in this way.

As the amount of ammonium nitrogen in the soil increases, so does the potential for conversion to ammonia. Although it can be generated from any fertilizer source that supplies nitrogen in the ammonium form, including urea, UAN, ammonium nitrate and diammonium phosphate (18-46-0), losses are greatest from urea. There is relatively little loss from surface-applied ammonium nitrate, and UAN is intermediate.

The rate at which nitrogen changes from the ammonium form to ammonia depends on the soil pH. When the pH is below 7.0, almost no ammonia is released. As the pH increases, the production of ammonia increases exponentially.

Ammonia loss can occur even if the initial pH of the soil is below 7.0. When urea is converted to ammonium, the pH of the soil immediately surrounding the fertilizer is increased. This effect is localized and temporary, but it can push the pH over 7, thereby greatly increasing the production of ammonia. Soils differ in their ability to resist this change in pH. The pH change, and hence ammonia loss, is likely to be greatest in sandier soils and those low in organic matter.

Soil moisture and rainfall are important factors in ammonia loss. Before any reactions can occur, the nitrogen must be dissolved in water. Thus, little nitrogen is lost from urea sitting on dry soil. Significant losses can occur, however, if urea is left on the surface of moist soil where there is enough moisture present to dissolve the urea but not to move it into the soil. Rain within a day after application of the urea can eliminate the problem. Depending on the soil texture, 15 to 25 mm of rain will take the nitrogen far enough into the soil to prevent ammonia from reaching the air.

The faster the urea is converted to ammonium, the greater the potential for loss. (A rapid conversion is likely to increase both the level of ammonium nitrogen in the soil and the pH change.) Thus, weather conditions play a role in determining ammonia losses. Warm temperatures speed the conversion of urea to ammonium, thereby increasing the potential for loss. (Topdressing of winter wheat with urea is possible because of the low temperature.)

Ammonia volatilization is of particular concern in reduced tillage systems. The production of ammonium nitrogen from urea is controlled by an enzyme present in soil, known as urease. The more urease there is, the faster the conversion occurs. This enzyme is also in crop residues. The more crop residues there are in contact with the urea, the greater the potential for ammonia losses. In addition, residues may prevent the urea or UAN from reaching the soil and they also keep the soil surface moist.

The best way to reduce ammonia loss is to incorporate or inject the urea or UAN into the soil. A shallow incorporation is sufficient. Where there is a large amount of residue on the soil surface, it will be necessary to aply the fertilizer under the residue. Where it is not possible to incorporate urea or UAN (eg. on pastures or winter wheat), applv it during cool weather or when rainfall is imminent.

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